

Gender differences in Korean high school students' science achievements and attitudes towards science in three different school settings

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This study analysed the effect of high schools' gender organization on Korean tenth-grade students' science achievements, and their attitudes towards science. The high schools involved included an all-male institution, an all-female institution, and a co-educational institution. Three schools, three principals, three science teachers, and 302 tenth-grade students from their respective school types responded to an initial survey, and eleven academically outstanding students were subsequently interviewed. Also, the students' pencil and paper tests—which included second semester midterms, and final exams containing their general science test scores—were collected from each school. The questionnaire responses and the transcribed interview sections were analysed using One-Way ANOVA, followed by Post Hoc analysis, constant comparison, and content analysis. Results indicated that the male and female students from the co-ed school had significantly higher science achievement and positive attitudes towards science. Interview transcripts of the selected students from the all-male, the all-female, and the co-ed schools confirmed the findings. Later discussion addresses the improvement of the Korean science curriculum, of learning environments, of the teachers' and students' roles in the classroom, and of education policies.

Introduction

In Korea, where natural resources are very scarce, one of the fundamental tenets of Korean culture is that intellectual resources *must* be maximized for successful advancement of critical national goals. As a result, the development of science and technology has been the most prominently emphasized area of education, resulting in Korea consistently ranking in the top five of all nations, in science and math proficiency. Furthermore, the government has accelerated the development of science and technology ever more intensely in order to maximize industrial improvement.

Apart from these efforts to improve science and technology in Korea, some studies in Korea provide evidence that female students have fewer science-related experiences than male students. Lee and Cho (1985) found that fewer high school girls than boys had significant experience with scientific activities, especially with extracurricular scientific activities. Kim and Lee's (1996) survey about the educational effects of science camps demonstrated that male students' participation was far higher than female students' participation: (by 21.9%).

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Kim and Chea (1997) also confirmed that male students ranked higher than female students in terms of their participation in school science clubs. Yoon (2002) as well, found that male students consistently chose science-related career paths and scientific activities more often than female students.

Hong, Park, and Kim (2001), analysing the achievements in science results of the TIMSS-R test, reported that even though the average gender differences of Korean students showed a decrease from TIMSS in 1995 to TIMSS-R in 1999, scores were still significantly higher than the international average. The gap differences in the average scores of achievement between male and female students by subject were most prominent in physics, chemistry, earth science, and environmental and resource issues respectively.

All in all, in Korea, there are a number of confirmations from the studies, that female students have experienced significant disadvantages in science education. Yet, these studies were conducted mostly based on large-scale survey data, instead of microscopic qualitative investigations. Therefore, this mixed methods study was designed to (a) identify school's differing gender organizations—from the perspectives of principals and science teachers, (b) investigate Korean high school students' science achievements and attitudes towards science in different gender settings, and finally (c) explore how students from different gender settings perceived science. This study explores four main questions, which are:

- (1) How were the three schools different or similar in terms of their science learning environments?
- (2) Do the students who have been taught in all-male (AM), all-female (AF), or co-educational (CE) school settings have different levels of scientific achievement and attitudes towards science?
- (3) How did students of both genders from these different settings perceive science?

Theoretical Framework

School as a Living Culture

School, which consists of administrators, teachers, students, and materials, should be a place where males and females can learn equally. School is not just a building. It is a living culture with constant interactions, and the students grow within that environment. School is an organism that has to accommodate students better. Students are growing every minute within our society's norms or culture. According to Bourdieu and Passeron (1990), "reproduction" connects cultural phenomena firmly to the structural characteristics of a society and shows how the culture is produced by this structure in turn helping to maintain it. They also show how education carries an essentially arbitrary cultural scheme, which is actually, though not in appearance, based on power. More widely, the reproduction of culture through education is shown to play a key part in the reproduction of the whole social system.

Renchler (1992) found that every school has its own patterns of values, beliefs, and traditions that have been made by both each school's administrators, teachers, students, histories and social system, and context. School is a sum of the values, cultures, safety practices, and organizational structures, not a building with people inside it.

One of the reports of the Southwest Educational Development Laboratory (SEDL) about school context, conceptualized school culture with three elements (Boyd, 1992). The first

element is the attitudes and beliefs held by persons both inside and outside the school particularly attitudes about schooling, change, students, and other persons. The second is the cultural norms of the school composed of the set of informal, unwritten rules governing behaviour in the school and community. Finally, school culture is created by the relationships of persons inside the school, on both individual and group levels. The ways in which teachers relate to other teachers, students and teachers interact, and the relationships between teachers and administrators are examples of this element.

Literature Review

Single-Sex vs. Coeducation

There is a debate between advocates of single sex education (Jimenez & Lockheed, 1989; Lee & Bryk, 1986, 1989; Lee & Marks, 1990; Mael, 1998), and advocates of co-education (Dale, 1974; Marsh, Owens, Myers, & Smith, 1989; Schneider & Coutts, 1982). Many researchers have found that girls in single-sex schools performed better than their coeducational school counterparts (Baker, 2002; Jimenez & Lockheed, 1989; Lee & Marks, 1990; Mael, 1998). They stated that this type of schooling was beneficial for building successful female career aspirations and self-esteem, and also made girls feel empowered and intelligent. They claimed that coed classrooms fostered gender inequities, and were only beneficial for males (Baker, 2002; Mael, 1998). Lee and Marks (1990) suggested that girls who attended coeducational schools needed to develop higher aspirations and goals, and they suggested that schools form a committee to monitor gender equity.

Holland and Eisenhart (1990), in their large comprehensive study of two universities—one primarily white in an affluent and prestigious suburban community—the other primarily African American located in a poor inner city area, concluded that:

Same-sex groups, like Willis's lads or McRobbies' girls, seem but a limited part of the picture. From the subsequent research, what seems more likely is that many girls (and boys) participate in larger, more diverse peer cultures or student cultures, which are coed. Our study, too, reveals coed student cultures and indicates that these mixed peer groups have great consequences for the women involved. (Holland & Eisenhart, 1990, p 46)

Some researchers pointed out that certain student experiences can also affect gender differences in science. Even though male and female students were in the same classrooms, the gaps in their educational experiences were very wide (Baker, 1987). By the age of nine, boys, in greater numbers than girls, claimed to engage more frequently in "tinkering" activities out of school (Johnson, 1987). Researchers concluded that because of these early-established differences in interests and activities, girls appeared to develop a very restricted view of science and its capabilities, and did not adequately or effectively envision themselves as future scientists (Kahle & Lakes, 1983).

Moreover, some studies have identified teacher interactions and classroom instructions as important factors. Baker, Leary and Trammel (1992) found that 2nd and 5th grade students liked science, but not as a subject taught in school. Piburn and Baker (1993) proposed that to promote girls' motivation in science, it must be taught differently. For instance, it seems certain that educators need to build environments that foster group study as well as the use of more hands-on activities and open-ended laboratories.

Science Achievements and Attitudes Towards Science

Men's Attitude towards Science as more Positive than those of Women

Ahn, Kim, and Soe (1985), adopting the scheme of categories of science education created by Klopfer, found that 91% of participants said they liked lab experiments. Male students, however, had a more positive attitude in certain subcategories—attitudes towards science and scientists, enjoyment in learning science, participation in science-related activities, and interest in science research—than that of females. Kim, Chung, Jeong, Yang and Kim (1999), performed a longitudinal study of three trends in Korean students' science-related abilities: 1) Cognition of science, 2) Interest in science, and 3) Scientific attitudes. They stated that male students showed higher scores for all these characteristics.

Ye, Skoog, and Zhu (2000), provided Chinese secondary schools data to supplement the Third International Mathematics and Science Study (TIMSS). They found that in most science-related subjects, male students' attitudes towards science were more positive than female students' attitudes. Cannon and Simpson (1985) found that males had more positive attitudes towards science and achieved higher recognition in science than females, even though female students were more motivated than males to achieve success in science. They also affirmed that this might be due to gender role stereotyping within our society. Hasan (1985), in a study of secondary school students in Jordan, found that male students who had better attitudes seemed to have positive perceptions of the science books, but negative perceptions of the science teachers. Female students, however, displayed the opposite pattern.

Women's Attitudes towards Science as more Positive than those of Men

Baker (1985), using both the Myers-Briggs Type Indicator (MBTI) and the Scientific Attitude Inventory (SAI), found that females had better science grades, indicating a more positive attitude towards science. She also stated that females did not possess the same level of decision-making skills, based on logical analysis that their male counterparts possessed. Instead they preferred to portray themselves as making decisions based on personal values.

Ye et al. (2000) found that female students had better attitudes and achievements in subjects like biology. This was supported by a study conducted by Scantlebury, Baker, Ayumi, and Atsushi (2002) on Japanese students. They indicated that in Japan, high school biology was not a course taken by males who planned to study science at the university, but was taken by females who planned to study science, or those who planned on pursuing a non-science major at the university.

Studies that Found No Difference, and Suggested Things to Consider

Harty and Beall (1984), in a study of gifted and normal fifth graders, found that there were no attitudinal gender differences between boys and girls. Rather, they found that there was a category where boys were more active than girls, which was "spending more time doing science experiments" (Harty & Beall, 1984, p483). Barrington and Hendricks (1988) studied 143 intellectually gifted and average third, seventh, and eleventh grade students. Although they expected gender differences in attitudes towards science and scientific knowledge, gender, as a separate variable, did not have a pronounced effect.

Some studies (Cannon & Simpson, 1985; Piburn & Baker, 1993; Scantlebury et al., 2002; Simpson & Oliver, 1985) have indicated that American, Chinese, and Japanese students seem

to have a degree of common ground, in that they both display a sharp decline in their attitudes toward science as their school years progress. Attitudes towards science at the beginning of the school years were more positive than towards the end (Cannon & Simpson, 1985). That is, science courses commonly taught to adolescent students in most school systems do not produce individuals with positive attitudes towards science, and do not produce students who are eager to continue taking science courses in high school and college (Simpson & Oliver, 1985). Furthermore, Simpson and Oliver (1985) found that for all students, attitudes towards science declined sharply from the beginning to the middle of the year within each grade.

Many researchers also pointed out differences in male/female preferred learning and teaching styles. Han (1986) investigated the development of scientific reasoning or logical thinking patterns of Korean secondary school students. He pointed out that the level of development of female students tended to be higher than that of males. He concluded, however, that during the period of development of logic there is a difference between males and females, according to the type of logic involved. Kim, Kim, and Kim (1990) indicated that although female students did not show significant differences between highly structured and less structured lesson, for the male students, a highly structured communication setting more successfully facilitated scientific achievement.

In the two-year study of Handley and Morse (1984), students' self-concepts/gender role perceptions were related to both their achievements and attitudes towards science. Harty, Samuel, and Beall (1986), using data from 228 sixth-grade students, found that attitudes towards science, interest in science, and science curiosity were highly related. They emphasized that in order to create classroom environments that encouraged student participation and focus on the development of more positive attitudes towards science, a greater interest in science and a higher level of science curiosity among students was crucial. Most importantly, Scantlebury et al. (2002) indicated that apart from suffering from the incorrigible belief in the "entrance exam hell" phenomena, and "equality in ability" in Japan (Ogawa, 2001, p590), sociocultural background was also one of the predictive factors for academic achievement and attitude in Japanese science education.

Methodology

The Context of the Study

Korean High School Students' Academic Styles and Lives as Based on Entrance Exams

Korea's high school students' academic styles combine three key ingredients: 1) Diligent and dedicated input of data, 2) Acute competitiveness with a drive to exceed average standards, and 3) Controlled and variably suppressed social lives (e.g. Ann, 2003; Kang, 2003; Kim, 2001).

A normal Korean high school starts at 6:50 a.m. and ends at 7:00 p.m. at night or later. Students are forced to study until this time while in school. The Korean Education System and Korea's cultural surroundings themselves force students to study in this manner (Kim, 2001; Kang, 2003). In many cases, to stand a chance of succeeding in the six-hour-plus test for admissions to the University level, most students cannot spend that much time in school, because they have to rush home for extra tutoring, which can normally last beyond midnight, regardless of school settings.

In Korean high schools, students are expected to select either the humanities or the sciences as

fields of study at the end of the first year, which is roughly equivalent in the American education system to expectations presented to students in the 10th grade. Therefore, it is important to note that this study explored students who had to choose either a humanities-track, or a science-track before they went to the 11th grade. The researcher defined school settings as either all-male (AM), all-female (AF), or co-educational (CE).

Participants and Overview of the Study

Participants for this study included three schools, three principals, three science teachers, and 302, 10th-grade students from the AM, AF, and CE high schools. They lived in one of the big suburban cities named Suwon, which is 30 minutes from the capital city, Seoul, in South Korea. In order to explore each school setting's particular environment, the researcher first surveyed a principal, and a science teacher from each school. For the "attitudes towards science" portion of the study, about 516 10th graders were selected by cluster sampling, then the researcher passed out the questionnaires. Ultimately only 393 out of 516 students from each school received questionnaires. However, only 302 out of 393 responses were included in the study. These students then participated in a 15-minute survey on their attitudes toward science. All science achievement scores, derived from a standardized test, were also collected for those who participated in the study. Finally, a total of 11 interviewees, who were identified as particularly high academic achievers, were selected. These students then participated in a two-hour interview with the researcher.

Data Collection

There were three data collection strategies used for the study. The first was a survey instrument for identifying the school's science learning environments, adopted from Lee and Pak's (1987) comparative study on the status of high school science education in Korea. In order to investigate attitudes towards science, this study adopted *The Affective, Behavioural intention, and Cognitive component Model (ABC model)* that has a Cronbach alpha of .95 (Lee, 1997). Also, students' second semester pencil and paper tests—their midterms and finals—on general science test scores were collected from each school. Finally, a list of questions for interviewing the 11 academically exceptional students was adopted and modified from Mason, Kahle, and Gardner's study (1991), and then further modified for interviewing Korean students. A group of students from each school was interviewed separately at a different location. Each interview lasted about two hours and all interview sessions were video-recorded. The study acquired IRB approval, and consent forms from all the participants and their parents. Pseudonyms were used for confidentiality purposes.

Data Analysis

This study adopted a mixed method, in which the researcher used both quantitative and qualitative methods for in-depth analysis. As for the quantitative method, the following steps were administered: 1) The *ABC model* questionnaires from the participants were scored and coded, both for the individual items and for the categorical items, using Microsoft EXCEL; 2) After data entry and coding, the researcher rechecked 30% of the scores for data cleaning; 3) The results of the scored data were transferred to summary data sheets for further uses; and 4) A One-Way analysis of variance (ANOVA, *F*-test, $\alpha = .05$), followed by a Post-hoc test were performed on the data from science test scores and attitudes, to test the statistical significance of the differences using Microsoft SPSS 16.0.

As for the qualitative method, the following steps were administered: 1) The researcher(s) used constant comparison analysis on differences and patterns on the principals' and science

teachers' questionnaires; 2) The researcher(s) transcribed the video-recorded interview session in Korean and English (a total of six and half hours); then 3) The researcher(s) worked to identify important themes or issues in the data using constant comparison analysis.

Findings

Question 1. How were the three schools different or similar in terms of their science learning environments?

The Three High Schools

The AM high school and the AF high school were located in a suburban district and established as private schools 18 and 17 years ago respectively. These two schools were surrounded by small residential areas and a freeway. The CE high school was a public school located near the central downtown district, and was surrounded by many commercial buildings and residential areas. The number of students enrolled in each school were 1750, 1600, and 1715 (male: 851, female: 864), respectively.

There were more science-track students than humanities students in the AM school. The ratio of Science to Humanities was 6 to 4. By contrast, in the AF and CE schools, there were more humanities-track students. More specifically, in the AF school, there were no significant discrepancies between science-track, and humanities-track students. However, the number of students in the humanities amounted to about one classroom more than the amount of students in the sciences. Also, the CE school reported that the number of students choosing humanities had increased, whereas the number of science-track students had decreased. However, there was no indication that this was gender related.

The Principals

The three principals were all male, and all in their late 50's, holding Master's or Bachelor's degrees in one of the Humanities. All had at least 15 years of teaching experience and less than five years as principals—with the exception of the CE principal who had 5-10 years of experience as a principal. The three principals reported that they would strongly support the extension of the science class hours per week, if they could. The AM and CE school principals also thought that science was very important in their schools, compared to subjects like Korean, English, and mathematics. However, of note, the principal from the AF school disagreed with them.

All three principals admitted that their schools' science teachers were very competent and excelled at their other jobs. Nevertheless, the principals from the single-sex schools thought that the training and encouragement of the school commissioners in their district were very poor. The principals from the AM and CE schools reported that their schools' lab equipment met the required national standards, and there were a lot of science related-books in their libraries. All three principals reported that they let science teachers use school funds for lab experiments freely. All principals had positive perceptions about inquiry-based learning in science and the influence of the material benefits of science. All principals strongly acknowledged that college entrance exams influenced science education in their schools.

When asked to explain why girls did not take as many science courses, the principal from the AM school strongly stated the following reasons: 1) females were not, as a whole, particularly interested in science jobs and 2) females perceive science as difficult. The principal from the

AF school strongly stated the following reasons: 1) females are not good at science and math; 2) females have little confidence in science inquiry; 3) females believe science is difficult; 4) many female students select non-science major courses; 5) few female students select science major courses; and 6) the impact of longstanding social and cultural traditions. Finally, the principal from the CE school strongly stated the following reasons: 1) females think science is difficult; and 2) many female students select non-science major courses.

Science Teachers

The three science teachers were all male, and in their 30's to 40's, holding Bachelor's degrees, except the one in the CE school who held a Doctoral degree. Their areas of discipline were AM: physics, AF: Earth science, and CE: Earth science. The science teachers from the three schools acknowledged that their principals understood science education well, but they were all skeptical as to the progress of current national amendments in science education.

All three of them reported that they had great confidence and understanding in their subjects, and that they wanted to be science teachers until they retired. Regardless of these commitments, the science teacher from the CE school stated that becoming a science teacher was actually not his true dream, and that he did not necessarily feel fortunate to be a science teacher. All three teachers spent a lot of time reading science-related books. However, they also spent a lot of time doing things other than teaching science at their school. In fact, because of this, the science teacher from the CE school thought he sometimes did not have enough time to prepare for his classes.

As for the professional development programs and encouragement from school administrators, the science teachers all had very negative attitudes about getting useful help from them. In contrast to the principals' perspectives on science learning environments, the classroom *teachers* from the AM and CE schools thought that the quality of their schools' lab equipment was crude, and all science teachers believed that they did not have enough funds to conduct adequate lab experiments.

All science teachers used a textbook to teach science, and conceded that their teaching methods were usually teacher-centered. Like the principals, all science teachers agreed that the college entrance exam influenced science teaching in their schools. When asked to explain why girls do not take science courses, the science teachers from the AM and AF schools stated the following reasons: 1) females are not good at science and math; 2) females have no confidence in their abilities to understand scientific inquiry; 3) females perceive science as difficult; 4) there are inherent, biological, "hard-wiring" differences between males and females, and 5) there are social/cultural traditions that contribute to the problem. The science teacher from AF thought that female students were not good at science and math, "Because there are many complicated steps in science to build a theory which require mathematical and analytical reasoning." The science teacher from the CE school strongly stated the following reasons: 1) Females are not interested in scientific subjects, and; 2) Females are not interested in scientific jobs.

Question 2. Do the students who have been taught in all-male (AM), all-female (AF), or co-educational (CE) school settings have different levels of scientific achievement and attitudes towards science?

The Students: Science Achievements and Attitudes Towards Science

The total student sample ($N=302$) was taken from three schools: AM ($n = 73$), AF ($n = 79$), male in CE ($n = 78$), and female in CE ($n = 72$). Science achievements and attitudes towards science were examined using ANOVA. An α level of .05 was used to test for significance between groups. The independent variable—the school type factor—included four levels: students in the AM school, students in the AF school, male students in the CE school, and female students in the CE school. The dependent variables were a) science achievements and b) attitudes towards science. The mean scores and standard deviations for science achievement scores and attitude scores for the school types are presented in Table 1.

Table 1: Mean Scores and Standard Deviations of Science Test Scores and Attitude Scores

	AM		AF		Male in CE		Female in CE	
	N = 73		N = 79		N = 78		N = 72	
	M	SD	M	SD	M	SD	M	SD
Science achievement Scores	73.88	17.99	74.11	13.72	79.21	17.06	81.85	13.61
Attitude Scores	173.48	45.48	166.15	38.91	185.79	31.74	185.36	34.40

*Bolted numbers indicate the higher scores among groups.

The ANOVA results indicated that the groups were significantly different in terms of science achievement scores: $F(3, 298) = 4.63, p = .003$, and the attitude scores, $F(3, 298) = 4.91, p = .002$. Follow-up tests were conducted to evaluate pair-wise differences among the means. There was a significant difference in the means between the students from the single-sex schools and the female students in the CE school, but no significant differences were found between male students in the CE school, and female students in the CE school. There were also no significant differences between the male students in the CE school, and the students from the single-sex schools; or between the students from the AM and the AF schools. As for the attitude scores, there was a significant difference in the means between the students from the AF school and the male students in the CE school; and between the students from the AF school and the female students in the CE school.

Question 3. How did students of both genders from these different settings perceive science?

The Interviews with 11 academically Strong Students

Interviewees' Background Information. All of the students reported that their socioeconomic status (SES) was middle class, and that their science grades were good. Most of the students reported that they were interested in science. Six students were satisfied with their science classes at school, and two students reported that their parents encouraged their efforts as science students.

The interviewer (Int.) asked about the images of scientists, including details such as the kind of people scientists were, how the students developed these images, and what the nationalities

of various known scientists were. The students tended to have standard, stereotypic images of scientists, who were “men who wear white coats, and work in laboratories,” “who may be unshaven and unkempt,” and who are “surrounded by equipment doing experiments.”

DeaShik's (am S2) ideas were especially stereotypical of scientists, and his description was perfectly matched with Mead and Metraux's findings. Strangely enough, JeeSun (af S2), who was from the all-female school, constantly described what scientists were doing and said that science was very difficult and complicated. Interestingly, most of the students from the co-ed school thought that a scientist was not that different from other “normal” people—that they simply had science-related jobs. Following are some interesting and typical excerpts from interviews with students about their perceptions of science:

Dea-Shik (AM-S2): “...they have white hair, because scientists think, and do experiments too much, blowing things up or exploding something. Because they are so into their experiments, their eyes are getting bad, so they wear black-rimmed glasses. They always stay inside the lab, so their shoulders become smaller...they are always holding a flask, mixing something, or blowing something up. They are always sitting, so their legs are so short. They are worn out. They always work 24 hours...they are thinking about their experiments even while they are eating. When they succeed, then they come out to see the sun...”

Jee-Sun (AF-S2): “Of a scientist? Well, science is very complicated and difficult; therefore, when you study it, you will change into or become stranger person. Studying science is too hard. Also, scientists are the people who do lots of experiments and who have a lot of curiosity...and who always pick apart everything, because they want to know the reason for everything. So, from a layperson's point of view, they seem invasive.”

Young-Tae (CE-male-S2): “I don't think they always wear a white coat and do experiments. In my mind, scientists would vary; like they can invent something new to improve our lives or they can build a spaceship. There are no big differences between normal people and scientists. However they are interested in very tiny, trivial things that are related to science.”

Sook (CE-female-S1): “They are just doing experiments or doing science-related works in labs. I think they are just like normal people. I don't think they are that much different.”

The students were then asked a computer/Kimchi refrigerator question in order to identify their trust in men and women scientists' work. In Korea, Kimchi is a traditional food that needs to ferment under the ground for a period of time. In contemporary times, scientists made Kimchi refrigerators for fermentation and preservation, and these refrigerators became a necessity for Koreans.

All of the students from the single-sex schools admitted that they would buy a computer and a Kimchi refrigerator that were made by men. However, the students from the CE school adamantly responded that the question itself carried anachronistic assumptions. In Sunny's case, it seems that her discouraging life-experiences impeded the possibility of her venturing into scientific endeavors.

Q5. Int.: The computer vs. Kimchi refrigerator story: “Let's just imagine that we have two computers. One was made by men, and the other was made by women. Which one will you buy? Can you tell me the reason? Then in another story, but with the same situation, “What is the case for buying the Kimchi refrigerator then?”

Seong-Min (AM-S3): “I think it is a prevalent notion that people think men are good at things like computers, so if the computer was made by women, in the corner of our minds there would be a doubt.”

Soon-Hee (AF-S1): “I would buy a computer that was made by men. Because, deeply seated in my mind is the idea that science is male. There are so many male scientists.”

Jun-Hyuck (CE-male-S1): “I don't care who made what. I would just look for the differences...”

Sunny (CE-female-S2): "...female scientists are good at designing, but when I heard that question, I thought I would buy ones made by men. Whenever our computer acted up, the people who came to our house and fixed it were men. That's why I think men are good at tinkering with machines. As for the Kimchi refrigerator, I would buy ones made by women. ...they don't know about refrigerators. One day, I told my dad that it was too hard to open the door of the refrigerator when I was holding dishes. So I told my dad that it would be really comfortable if there was an automatic button under the door. Then my dad told me that that was a good idea. So I brought up that idea in my science invention class, and you know what my science teacher told me? He said, 'What's the difference?' I was really discouraged. However, most of my female friends agreed with me. They really liked my idea."

The researcher received negative responses from students from the single-sex schools on being the husband or wife of a scientist question. The students from the AM school worried that their wives might not have time to do housework, or take care of babies. The students from the AF school thought that being the wife of a scientist would make them lonely. By contrast, all of the students from the CE schools, except Sunny, held very positive conceptions of being the husband or wife of a scientist. Sook, who thought that scientists were just normal people, pointed out the importance of a husband's characteristics. The male students from the CE school said they would help their scientist wives when they were period. They said that they would like to be the husband of a scientist because they liked and understood how scientific works were accomplished:

Su-Sup (AM-S1): "I am kind of a very conservative person. So, if my wife were a scientist, there would be no happiness in our house. Things are scattered everywhere like a pig sty, kids are crying...those pictures are coming to my mind...Of course this is the 21st century, which is an era of doing housework together, but she has to cling to her experiments, not her family...But, if she were a great or prominent scientist, I would support her...but I would still feel there was something wrong..."

Jee-Sun (AF-S2): "I would be lonely. Because experiments do not end quickly, even if his body was at home, his mind would linger on his experiment, so...it would be hard to understand him."

Young-Tae (CE-male-S2): "...Because I have interests in those fields, we could discuss many things together...there's no problem for me. I don't care whether she is good at doing housework or not, because I could help her."

Sook (CE-female-S1): "I think it depends on that person's character. I don't think that just because he is a scientist he always has to do experiments. If my husband thinks he is the center of the family, he can balance both family and work at the same time. So, I could live happily with him. However, if he's always doing his work and doesn't come home, I would probably not marry him in the first place."

Eun-Kyung (CE-female-S3): "I don't care whether my husband is a scientist or not. I will do my work and he will do his work. I like that."

To summarize, the results of the study indicate that there were significant differences in students from the three different school types, regarding scientific achievements, and their attitudes towards science. As evidence has shown, it is apparent that the students from the CE school had high achievement scores, *and* positive attitudes towards science.

Conclusions

The study shows that all the principals and science teachers had stereotypic perceptions regarding female students learning science, but only students from the CE school held more non-stereotypic perceptions about science than the single-sex schools. The students from the single-sex schools, where there was insufficient support from the district, showed

limited and stereotypical understandings of each gender. As for the students from the CE school, it was also possible that when female students and male students were learning together, they were making visible or invisible interactions that affected their learning, future careers, even acquiring better understandings of the opposite sex.

Most importantly, this study's findings also indicated that the students from the AF school had the highest likelihood of not using their talents in science, and the students from the AM school had the highest likelihood of maintaining their stereotypical perceptions of science and scientists. For instance, the results of the study demonstrate that their schools had poor support from their district, had poor lab equipment, and had few science-related books in their libraries. Their principals and science teachers had negative attitudes towards science, and stereotypical perceptions about female students. Finally, these facts negatively impacted female students' science achievements and their attitudes towards science.

The results of the study supports the work of others (Dale, 1974; Marsh et al., 1989; Schneider & Coutts, 1982), in finding that the male and female students from the CE school had significantly higher science achievements, and better attitudes towards science—but significantly lower stereotypical images of scientists. Throughout the results, findings are contrasted with those that resulted from researchers advocating single-sex (Jimenez & Lockheed, 1989; Lee & Bryk, 1986; Lee & Marks, 1990; Mael, 1998).

Implications

According to the 1995 and 1999 reports of the Third International Mathematics and Science Study (TIMSS), and the 2000 report of the Program for International Student Assessment (PISA) of the Organization for Economic Co-operation and Development (OECD), Korea was one of the countries that had the largest differences between male and female students' mathematics and science scores (Mullis, Martin, Fierros, Goldberg & Stemler, 2000). This study's findings indicated that if female students were in an AF school, their chances of succeeding in mathematics and science would be significantly lower.

Most scholars and researchers in science education generally agree that to give both male and female students an equal chance, and to foster success in science for both, they need to develop positive attitudes about science, positive perceptions of science and scientists, effective changes in school science teaching practices—and changes in Korea's national education policies. These changes should permeate the curricula, science learning environments, teaching styles, perceptions and attitudes toward science and science education, the behaviors of teachers and administrators, and the goals, norms, and cultures of schools and their communities (Banks, 2001).

Schools should have effective staff development programs, consisting of a wide variety of science program components, including needs assessments, curriculum development, peer teaching, materials selection and evaluation, which explain the tremendous potential of gender equalization especially regarding Science, Technology, Engineering, and Mathematics (STEM) curricula. Schools should also use interdisciplinary and multidisciplinary approaches in designing and implementing their science curricula. For instance, curricula should optimally maximize the use of experimental learning, especially through local, community based resources and parents.

Curricula can also be influenced by teachers and students, who can make individual efforts that, integrated together, optimize chances for a unified movement towards gender equity in

science. This is all the more important when it is realized that successfully bringing females into the arena of science and technology arena *could almost double the human resources available for Korea to draw upon to further its success as a nation*. If it is true that the primary resource of Korea and other similarly situated developing countries is its pool of intellectual potential, then bringing females into the science and technology arena would arguably be one of the very most important priorities for available changes in existing educational systems.

Females, after all, have just as much potential as their male counterparts when it comes to success at any intellectual achievement, if started early and with the right cultural milieu designed to minimize and overcome cultural barriers that are nothing more than obsolete impediments in any modern educational system. Doubling the intellectual power of a country's workforce in science and technology areas has tremendous potential for helping the country survive, prosper, and advance in relation to other ever competitive countries. Can we afford to continue to engender cultural milieus that inhibit such advances?

When teachers encounter such gender issues in science, they need to approach them directly. From movies to magazines, from picture books to real life, teachers need to identify sexism when they see it, and directly explain to their students the roles now opening to women (Sadker & Sadker, 1995), and the many potential rewards of succeeding at them. In order to monitor accurately who receives their attention, teachers would be advised to invite qualified outside observer into their classroom—such as an open-minded colleague, parent, or even a student. Then teachers can share their experiences and work on objectively identifying and changing their environments and their behaviours.

To provide action to make the teaching of open-ended approaches work, teachers should seek as many on-line resources as possible, resources that can help them provide worthwhile and truly engaging activities for students of both genders. In addition, although the cultural expectations of gender roles in Korea is still distinctive in rural areas, as it typically is in many other countries—women are largely confined to the home as a housewife or mother—the participants of the study showed quite egalitarian views related to the future roles of women in scientific fields. With the improved equalization of gender perception and expectations, teachers need to find proper ways of delivering traditional and contemporary values at the same time, gracefully and effectively.

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